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BULLETIN
OF THE
AMERICAN GEOGRAPHICAL SOCIETY.

Vol. XXXVIII **1906.** **No. 8**

THE CLASSIFICATION OF CLIMATES: II.

BY

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Harvard University.

SYNOPSIS.

Supan's Climatic Provinces.—Köppen's Classification of Climates.—Hult's Classification of Climates.—Ravenstein's Hygrothermal Types.—Classification of Rainfall Systems.—Summary and Conclusions.

Supan's Climatic Provinces.—The ordinary classification into continental, marine, and mountain climates is too general. Some scheme of classification is needed in which the geographical factor plays an important part, and which recognizes the types of climate, possessing common characteristics of temperature, rainfall, and winds, which occur over areas having similar topographic conditions. A fairly simple scheme of this kind has been suggested by Supan, who recognizes thirty-five so-called climatic provinces,* but any such rigid subdivision is obviously susceptible of almost infinite modification. Twenty-one of these provinces are in the Eastern hemisphere, including Polynesia; twelve are in the Western, and two in the polar zones. The descriptions of these provinces are as follows:†

1. Arctic Province. This coincides with the north polar cold cap, the area wherein the mean temperature of the warmest summer month is never over 50° F., and within which trees do not grow.

2. West European Province. Mild winters, owing to influence of the westerly winds and Gulf Stream. Yearly temperature range

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* A. Supan: *Grundzüge der physischen Erdkunde*, 3d Ed., Leipzig, 1903, 211–214.

† Free translation of original, following Bartholomew's *Atlas of Meteorology*, p. 7.

under 59° F. (15° C.). Plentiful rainfall, fairly well distributed throughout the year, but varying in quantity owing to great diversity of land contours. The climatic conditions often vary in short distances, and hence the region can be divided into many subdivisions.

3. East European Province. Here the evidences of a land climate begin to be observed; but as most of the region is a plain, differences depend mainly on latitude. The rainfall is smaller than in Province 2, and gradually diminishes towards the south-east, and has a marked summer maximum.

4. West Siberian Province. This is separated from 3 by the limit of the positive annual isanomalous lines, which practically coincides with the Urals. The characteristic peculiarities of 3 are found here greatly emphasized, and the greater variability of temperature is to be noted.

5. East Siberian Province. A gradual rising of the ground is found east of the Yenisei, with low plains only along the rivers. The winter cold pole is here, and the yearly range of temperature is a maximum. As a rule, the rainfall is low.

6. Kamchatkan Province. The sea diminishes the temperature extremes noted in Province 5, and much rain falls.

7. Sino-Japanese Province. On the continent relatively well-marked winter cold, and strong periodical rains. In Japan these peculiarities are less extreme.

8. Asiatic Mountain and Plateau Province. This includes all the lofty plateaux bounded by mountain ranges, which shield it on every side, and so render it very dry. The great height makes the winter temperature severe; but the summer heat is great, owing to the continental position. The daily as well as the yearly range of temperature is very marked.

9. Aral Province. Dry low-lying plain, with the greatest rainfall in the north in summer, and in the south in winter. The plains of western Turkestan have severe winters and very hot summers.

10. Indus Province. A plain remarkable for great dryness and heat.

11. Mediterranean Province. Very varied in climate, owing to its great irregularity of outline, both horizontal and vertical. Mild, except on high plateaux. Winter rains.

12. Saharan Province. Reaches to Mesopotamia. Region of dry north winds, and probably the one receiving least rain. Its continental position and lack of vegetation increase the heat of

summer extraordinarily; both annual and daily ranges of temperature are considerable.

13. Tropical African Province. Owing to the height of the central plateau the heat is less intense, but it is very great on the narrow coastal plains. Tropical rains decreasing towards the west.

14. Kalahari Province. Includes all the almost rainless region of Southwest Africa.

15. Cape Province. Sub-tropical.

16. Indo-Australian Monsoon Province. Strong periodical rains are brought with the southwest and northwest monsoons, except at a few places in the archipelago. The temperature is fairly uniform, despite the great extent of the province, and the yearly range is very small.

17. Inner Australian Province. With great extremes of temperature. Irregular and rare rains.

18. Southwest Australian Province. Sub-tropical.

19. East Australian Province. It extends to the water-parting and includes the southeast coast and Tasmania. Plentiful and fairly regular rains. Moderate range of temperature.

20. New Zealand Province. Probably includes the small neighbouring islands. Mild climate, with fairly regular rains.

21. Tropical Polynesian Province. Tropical climate, ameliorated by the ocean, so that mild summer weather prevails throughout the year. On the loftier islands the rain is abundant, and has a tropical periodicity.

22. Hawaiian Province. Also a mild climate, but with subtropical rains.

23. Hudson (North Canadian) Province. Great extremes of temperature and little precipitation.

24. Northwest American Coastal Province. Mild, equable, rainy climate.

25. Californian Province. Relatively cool, especially in summer. Marked sub-tropical rainy seasons.

26. North American Mountain and Plateau Province. Great yearly and daily ranges. Dry.

27. Atlantic (East North American) Province. Great contrast in temperature conditions of north and south in winter. Extreme climate even on the coast. Plentiful rains, evenly distributed throughout the year. Great variability.

28. West Indian Province. This also includes the southern rim of North America. Equable temperature. Rain at all seasons, but with a marked summer maximum.

29. Tropical Cordilleran Province. On the interior plateau perpetual spring, owing to considerable height above sea-level. In Mexico and Central America marked zenithal rains; in South America more regular precipitation.

30. South American Tropical Province. Little that is certain is known about this province, which includes mountainous regions and plains, and ought, therefore, to possess considerable variety of climate.

31. Peruvian Province. This province extends as far south as 30° S., and so includes the northern part of Chile. Abnormally cool. Rainless.

32. North Chilian Province. Sub-tropical.

33. South Chilian Province. Equable temperatures, with cool summers. Extraordinarily rainy.

34. Pampa Province. Range of temperature fairly large, especially in the north. Rain not plentiful.

35. Antarctic Province. Resembles the Arctic, so far as can at present be determined, in winter cold, but differs in having a very low summer temperature and a very regular distribution of pressure and winds.

Fig. 1 shows the geographical distribution of these climatic provinces.*

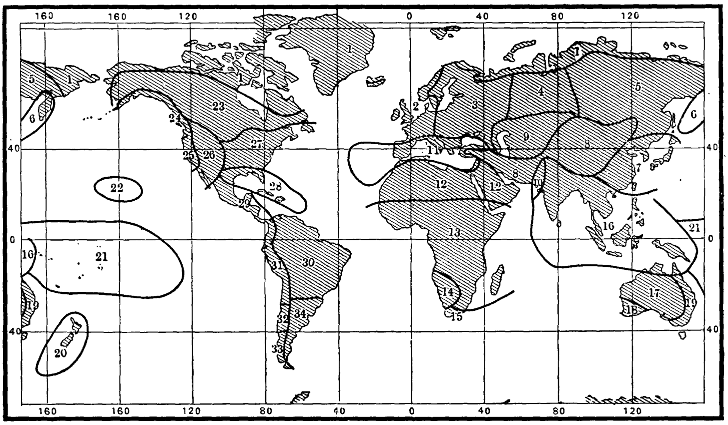

FIG. 1.—SUPAN'S CLIMATIC PROVINCES.

Köppen's Classification of Climates.†—An interesting classification of climates, from a botanical standpoint, is that proposed by

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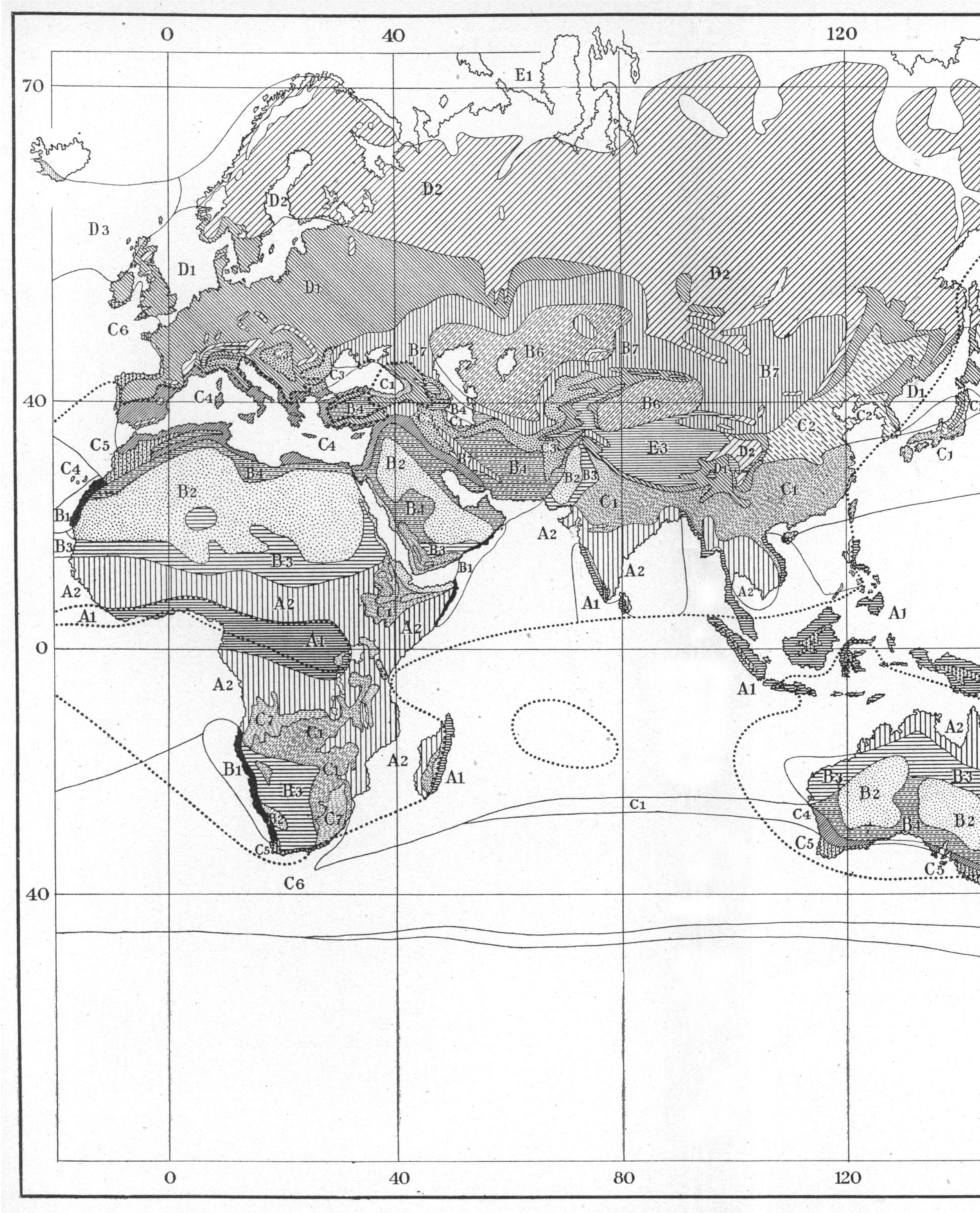
* From A. Supan: *Grundzüge der physischen Erdkunde*, Leipzig, 1903. Pl. XIV. The provinces are numbered somewhat differently in the original map.

† W. Köppen: *Versuch einer Klassifikation der Klimate, vorzugsweise nach ihren Beziehungen zur Pflanzenwelt.* Hettner's Geogr. Zeitschr., VI, Nov.-Dec., 1900. Reprinted. Pp. 45 8°. Leipzig, Teubner. Abstr. in *Met. Zeitschr.*, XVIII, 1901, 106-120.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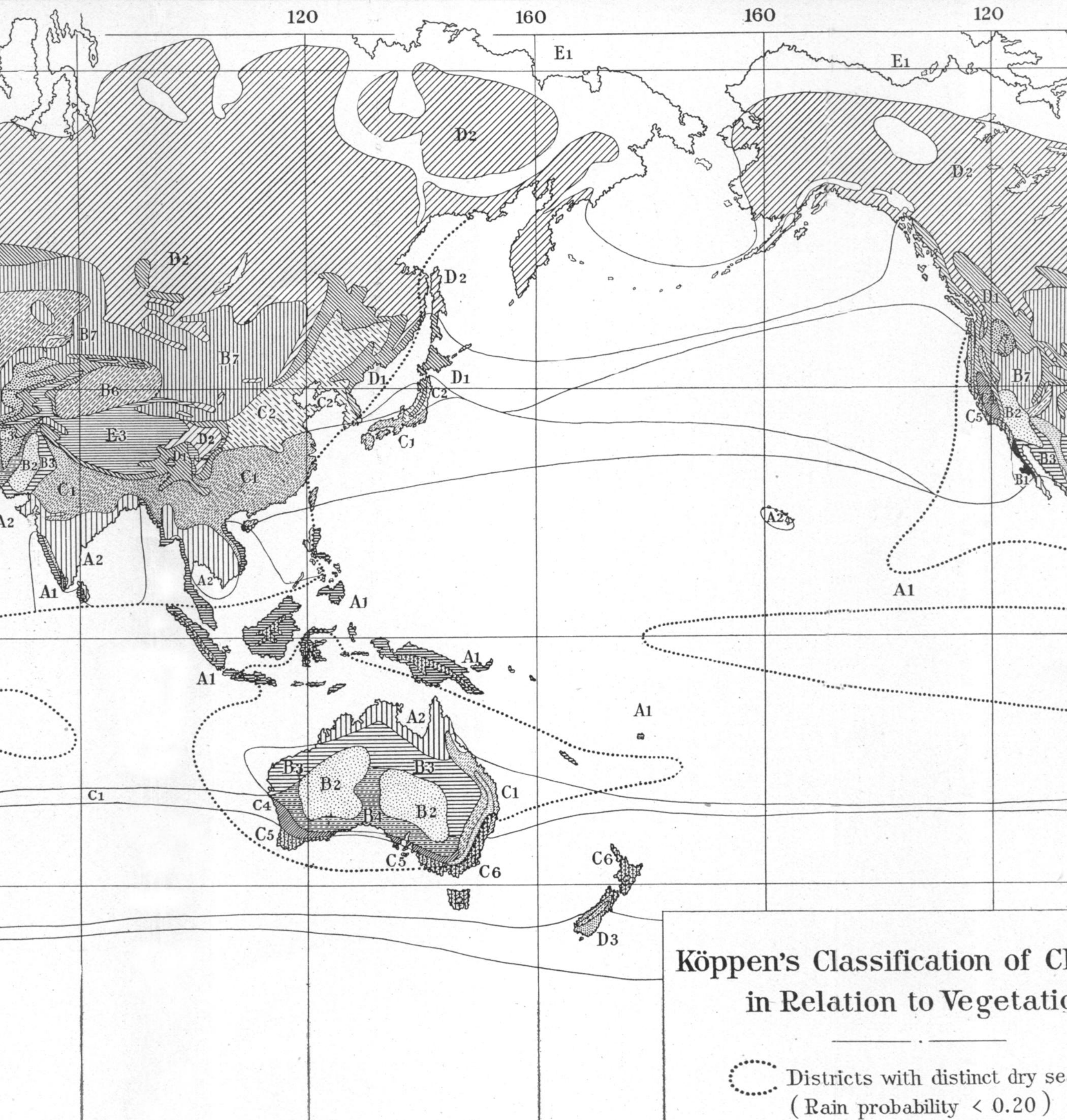120
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Köppen's Classification of Cl
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(Rain probability < 0.20)
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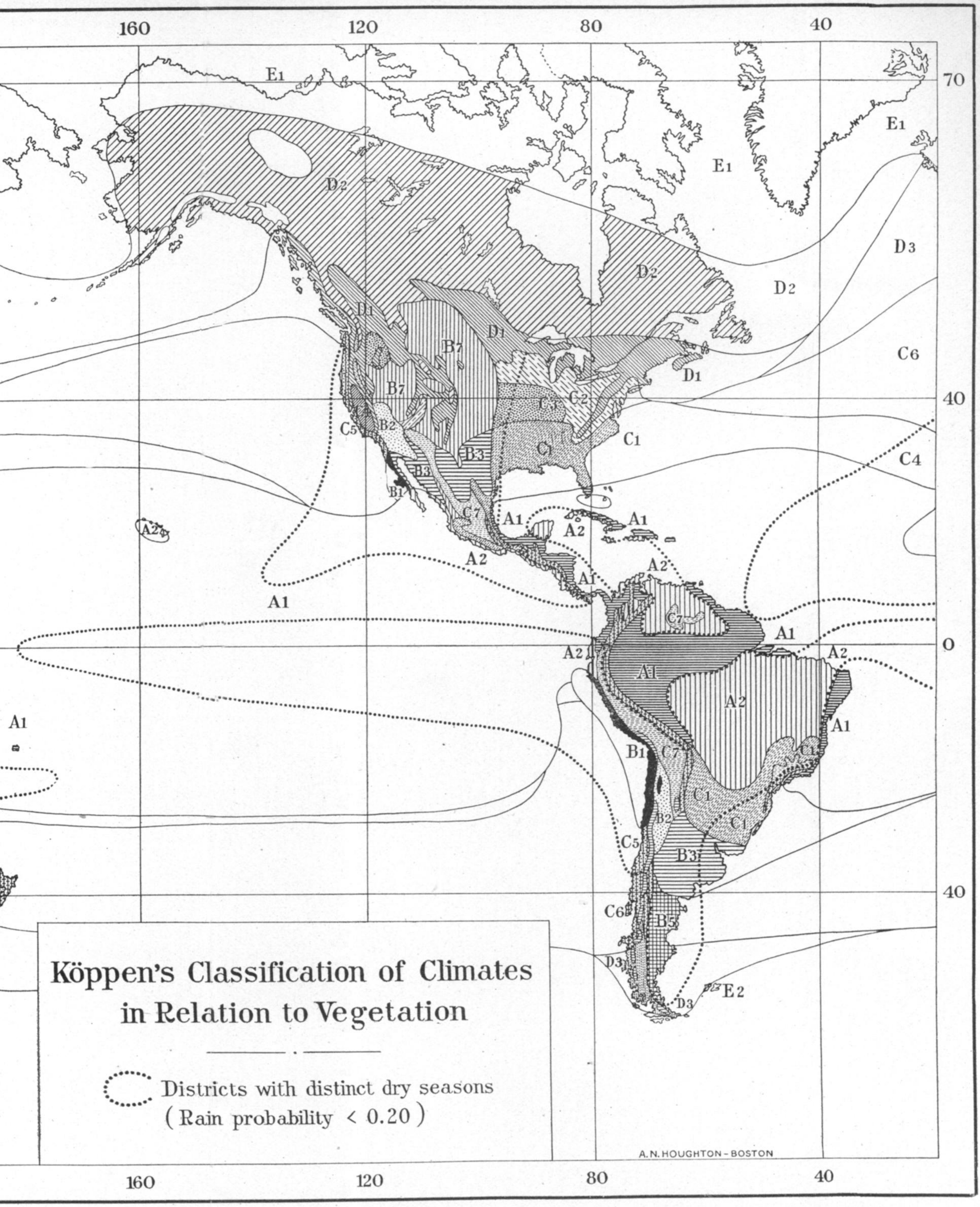
PLATE I.



Köppen's Classification of Climates in Relation to Vegetation

Districts with distinct dry seasons
(Rain probability < 0.20)

A. N. HOUGHTON - BOSTON

Köppen. This rests upon certain critical values of the temperature and rainfall of the warmest or coldest, or of the wettest and driest month. The plant classification proposed by A. de Candolle* in 1874, and later adopted by Drude,† is accepted. This is a division into five principal biological groups under the control of temperature and moisture, as follows:

A. *Megatherms:* plants which need continuously high temperature without much annual range, and also abundant moisture. There is no cool season; the temperature of the coolest month is over 64.5° (18° C.), and there is at least one month of heavy rain. When there are marked dry seasons the principal one comes in winter and spring. In parts of this belt there are two rainy seasons. In this belt are found the lofty tropical forests intertwined with vines and creepers—sago, betel, pepper, cacao, bread fruit, baobab, coffee, sugar cane, banana, ginger, and so on.

B. *Xerophytes:* plants which love dryness and need high temperatures, at least for a short season. These are found in tropical districts which have a long dry season, and in the steppes and deserts of the tropics and of the warmer parts of the temperate zones. They are adapted in various ways for life in a dry climate; they rest during the dry time, and, in extreme cases, where rain may not fall for years, they survive as seeds. The vegetation varies with the soil. In this group we find the date, mesquite, acacia, cactus, agave, and similar plants.

C. *Mesotherms:* need moderate heat (59°–68°) and a moderate amount of moisture; some require high summer temperatures; others shun low winter temperatures; others shun the dryness which often accompanies high summer temperatures. These plants inhabit latitudes between 22° and 45° N. or 40° S., as long as the moisture continues sufficient. There is a cool season—coldest month below 64.5° (18° C.)—and a hot summer,—warmest month over 72° (22° C.),—or a mild winter—coldest month over 43° (6° C.),—or both. The classic Mediterranean climate is found in this belt. The mesotherm belt contains the tea, maté, rice, cotton, magnolia, hickory, arbor vitæ, hemlock, wheat, corn, olive, fig, grape, heath, cinchona, etc.

D. *Mikrotherms:* need less heat, lower mean annual temperature, cooler and shorter summers, and colder winters. The warmest month is at least 50° (10° C.) and not over 72° (22° C.); the coldest is below 43° (6° C.), with at least an occasional snow-cover in winter and sufficient rainfall in the warmer season. Evergreen and deciduous forests, grains, and in the warmer portions fruit and corn are found.

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* A. de Candolle: Arch. Sci. Bibl. univ. de Genève, 1874.

† O. Drude: *Pflanzengeographie*, Stuttgart, 1890, p. 111.

E. *Hekistotherms:* plants of the Arctic zone, beyond the limits of tree growth and of the zone of scrubby Antarctic vegetation. These need the least heat. Mosses, lichens, and similar lowly forms are typical.

A simple scheme of distribution of these five groups of plants may first be developed with reference to an ideal continent, stretching from pole to pole, with oceans on both sides and without mountains (Fig. 2).* Here *a a* is the western and *b b* the eastern coast. The approximate latitudes are given at the margins. The groups of de Candolle's system are arranged as shown, if the xerophytes are limited to the deserts and steppes and if those woody plants of the megatherm and mesotherm zones which are adapted to a dry climate are included within these zones. The typical zonal arrangement is interrupted in latitudes 20° to 50° by the fact that the arid district of the xerophytes (B) is wedged in on the west coast between A and C. Farther east zone B broadens poleward, cuts through the middle of the mesotherm zone, and usually ends without reaching the east coast.

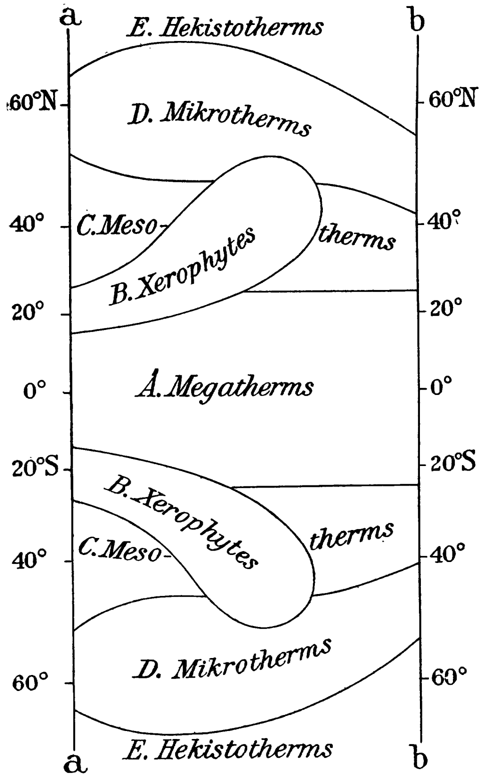

FIG. 2.—GENERAL DISTRIBUTION OF PLANT ZONES.

The five principal types are further subdivided until the whole number of climates reaches twenty-four. The special conditions which characterize each climate are carefully determined, and each sub-climate is named after one of its characteristic plants or animals; or after some distinctive meteorological phenomenon; or, again, after the general character of its vegetation. Fig. 3 gives the limits of the different sub-climates, and also the characteristic conditions of temperature and precipitation.* Fig. 4 gives the scheme of the sub-climates for the lowlands, with their names. Four climates which do not occur at sea-level are here lacking (C7, E3, E4, F).† The vertical distribution of these climates, much simplified, is shown in Fig. 5. The descent of the climatic strata from equator to higher latitudes is shown on the right for the con-

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* After Köppen, *ibid.*

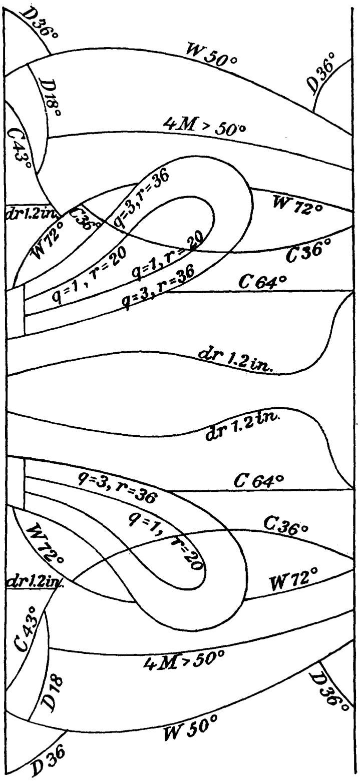

FIG. 3.—SCHEME OF CLIMATES AT SEA LEVEL.

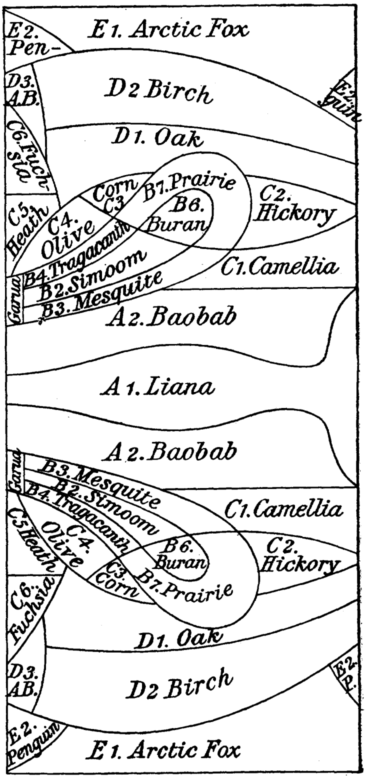

FIG. 4.—NAMES OF CLIMATES AT SEA LEVEL.

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* Figures are degrees Fahr. C = coldest month. W = warmest month. 4 M = 4 months. dr 1.2 in. = driest month rainfall 1.2 inches. D 18° and D 36° = difference between extreme months 18° and 36°. q = quotient obtained by dividing the amount of rainfall in the wettest month (in mm.) by the maximum vapour tension (in mm.) at the mean temperature of the same month, an expression which combines the effect of rainfall and evaporating power. r = rain probability of rainiest month.

† C7, High savanna climate; E3, Yak, or Pamir climate; E4, Chamois or High Alpine Climate; F, perpetual frost, without life.

tinental and on the left for the marine type, as far as about latitude 57 . Climates C1 to C4, and D1 and D2, have large temperature ranges, and are therefore lacking at the equator and on the ocean; while C5 to C7, and D3, have small ranges, and are not found on the continents of higher latitudes. The general control of pressure, winds and ocean currents over the climatic types is shown in the two following ideal diagrams, in which the two vertical lines indicate the west and east coasts of the ideal continent, and the area included reaches to the middle of the adjacent ideal oceans. The line 0°–0° is the equator (Figs. 6 and 7). The short arrows give the wind direction 500–1000 m. above the surface; calms are represented by the sign ⊙; the long broken arrows indicate the prevailing surface ocean currents. At *a a* there is a rise of cold water from beneath the surface of the ocean. The curving lines are sea-level isobars; the lower pressures are shaded. The letters and boundaries drawn in short slanting lines in Fig. 7 indicate the climatic districts of Fig. 2. Fig. 6 is similar to Fig. 7 as far as these climatic districts are concerned. Therefore the letters and boundaries are omitted. Plate I. shows the geographical distribution of the climatic types and subtypes.

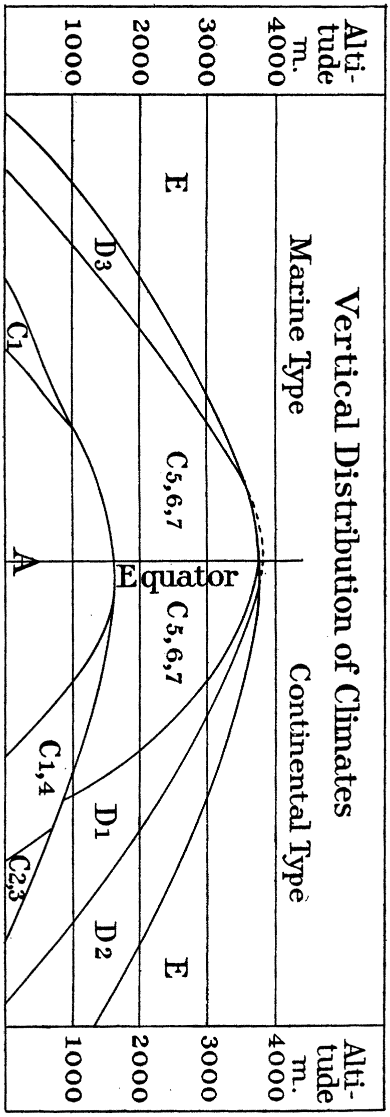

FIG. 5.—VERTICAL DISTRIBUTION OF CLIMATES.

*Hult's Classification of Climates.**—Another scheme of classifica-

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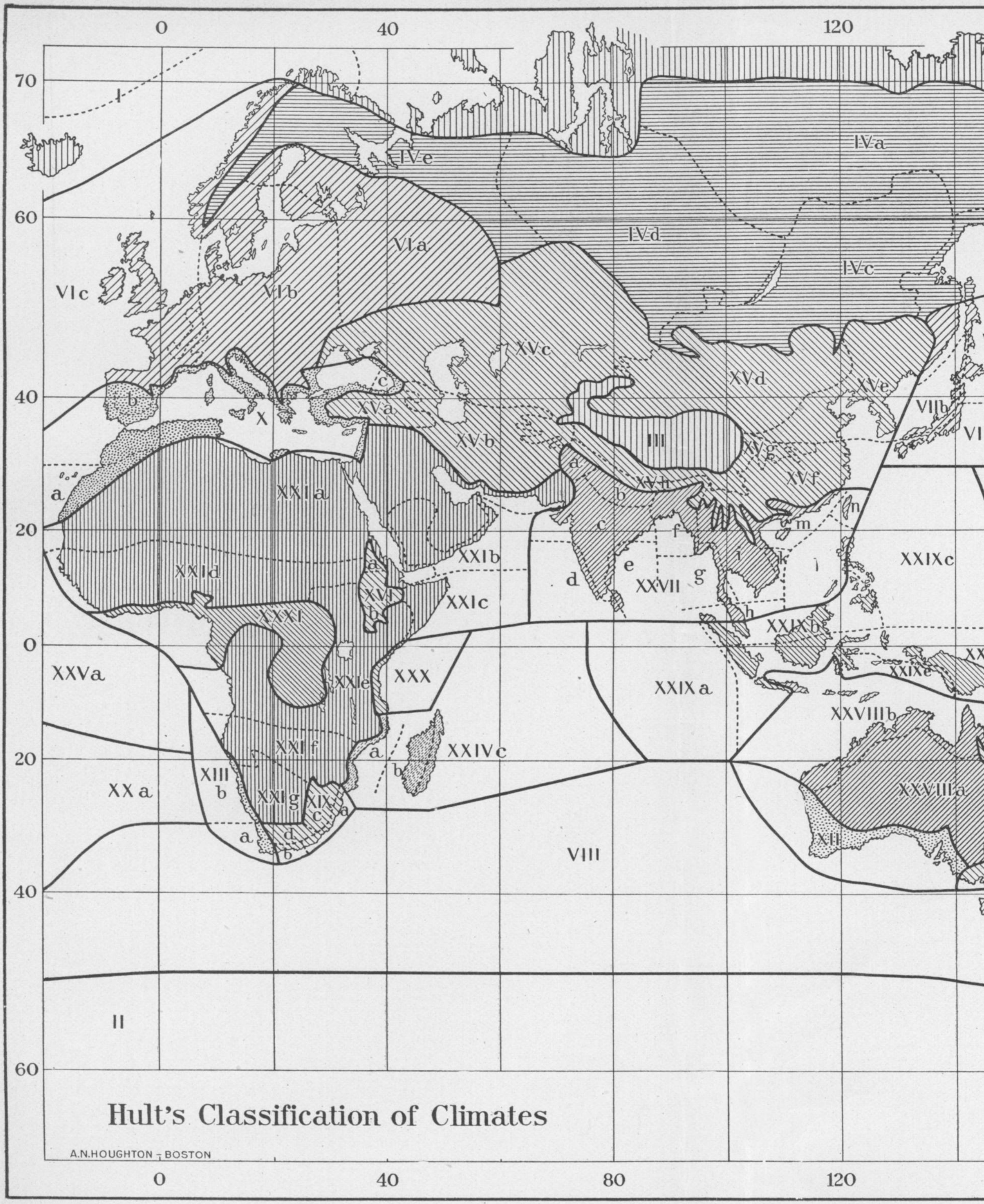
* R. Hult: *Jorden's Klimatområden. Försök till en indelning of Jordytan efter Klimatiska Grunder.* Vetenskap. Meddelanden af Geografiska Föreningen i Finland. I. 1892–93. Helsingfors, 1892–93, pp. 140–201. Chart XVI. Rev. *Met. Zeitschr.*, XII, 1895 (48)



Hult's Classification of Climates

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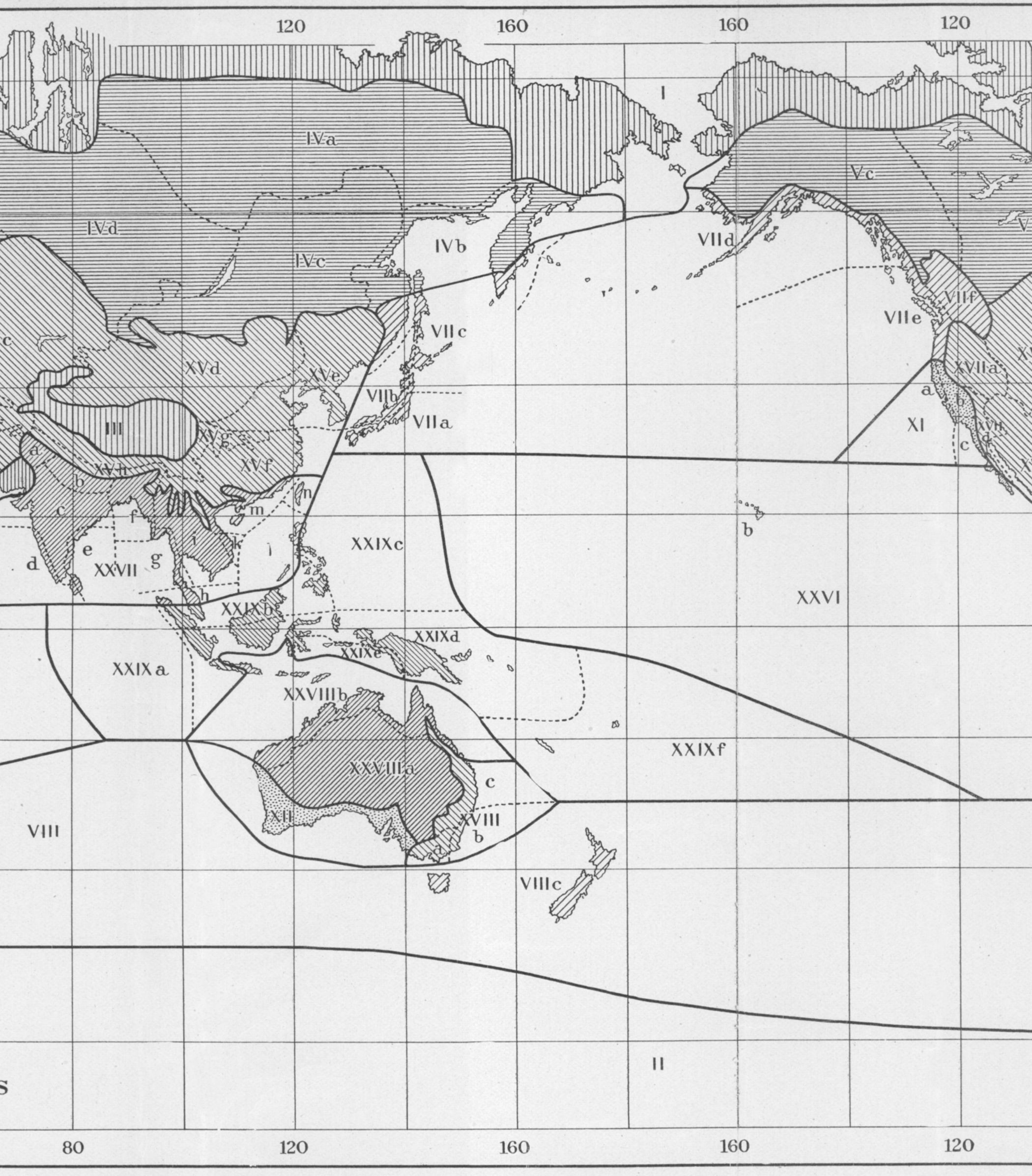
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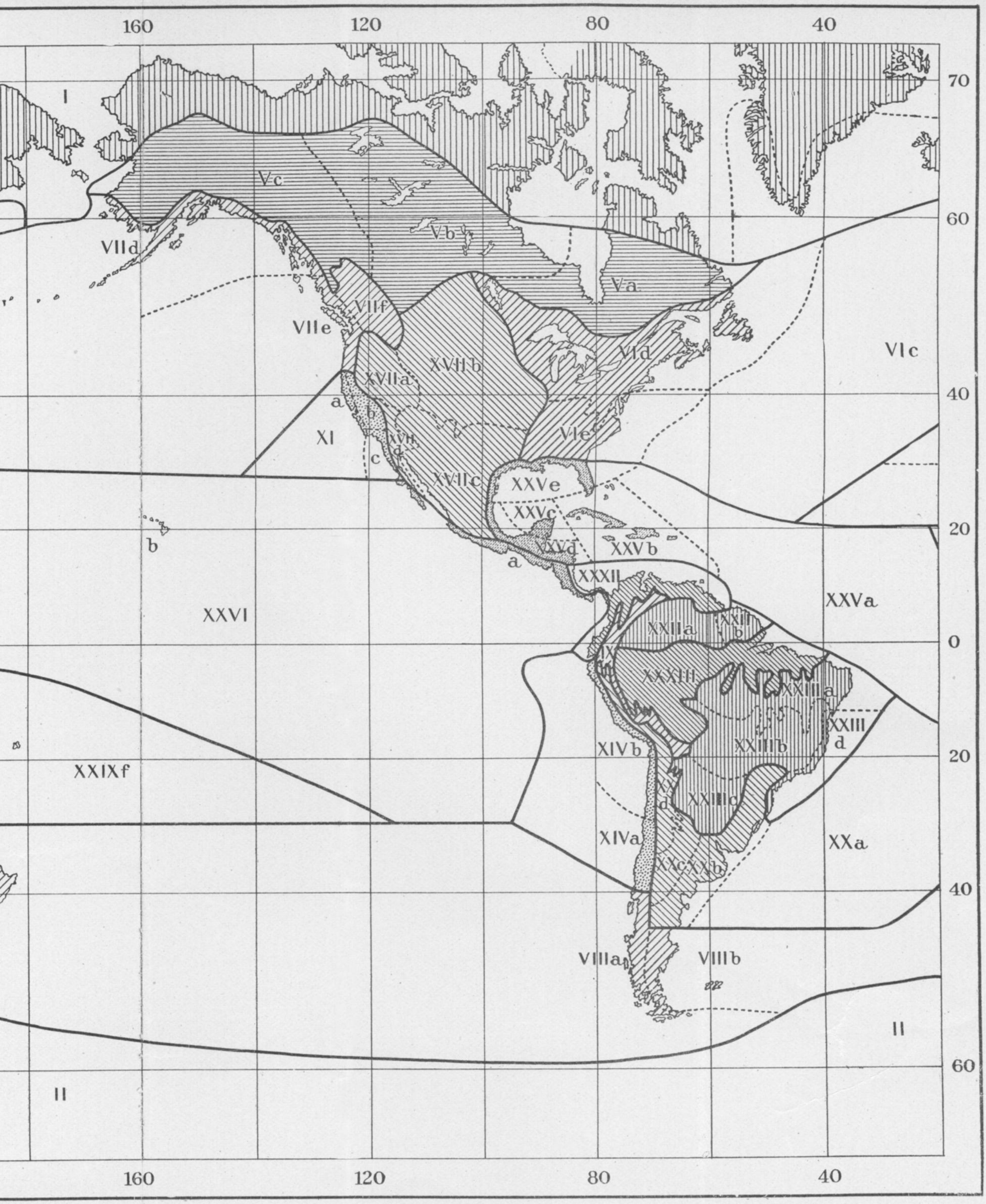
PLATE II.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tion, proposed by Hult, embraces three large divisions based upon differences in mean annual temperatures as follows: A. Cold districts, whose mean annual temperature (without reduction to sea-level) is below, or but slightly above, freezing. B. Temperate districts, with mean annual temperature of 32° to 68° F. C. Warm districts, with mean annual temperatures over 50°, and small annual range of temperature, the distribution of the rains and the changes in the winds being the chief characteristics of the seasons. These three main divisions are further subdivided on the basis of their seasonal characteristics of temperature, of winds or of precipitation into nine smaller districts, including thirty-three different climatic kingdoms. These latter are again subdivided into one hundred and three smaller provinces. The subdivisions, omitting the smaller provinces, are as follows: A. α. Districts with cold summers (warmest month⋜50°): I, Arctic; II, Antarctic; III, Tibet. β. Districts with warm summers: IV, Siberian; V, Hudson's Bay. B. α. Districts of prevailing westerly winds, with precipitation in

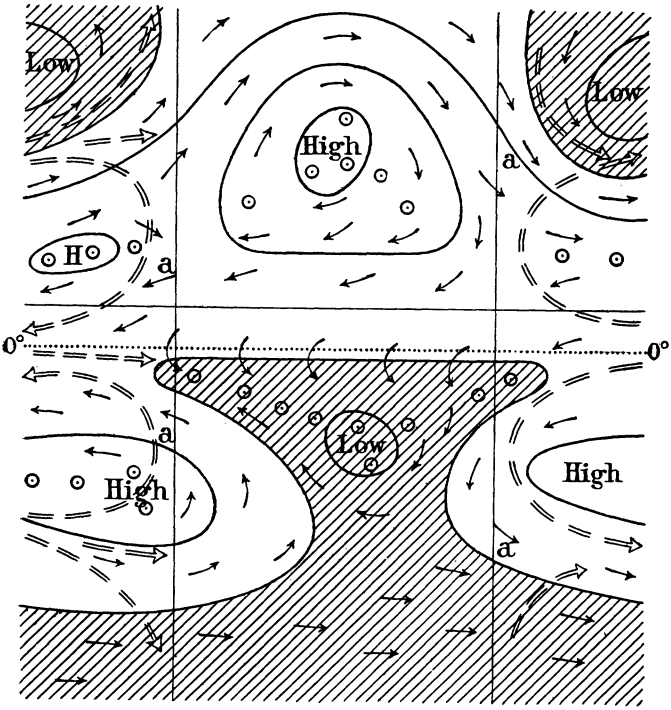

FIG. 6.—PRESSURE AND WINDS IN JANUARY.

all months and many cyclones: VI, Gulf Stream; VII, Kuro Siwo; VIII, South Pacific; IX, Andean. *β*. Districts with variable winds, winter rains and dry midsummers: X, Mediterranean; XI, Californian; XII, Southwest Australian; XIII, Benguela Current; XIV, Humboldt Current. *γ*. Districts with weak and irregular winds, summer rains, and with the principal dry season in winter: XV, Central Asiatic; XVI, Habesch; XVII, Rocky Mountain; XVIII, Blue Mountain; XIX, Orange Free State; XX, Pampa. C. *α*. Districts with one or two solstitial rainy seasons and with the trades weak or interrupted by local monsoons: XXI, African; XXII, Llanos; XXIII, Brazilian. *β*. Districts with normal trades and trade rains: XXIV, Madagascan; XXV, Caribbean; XXVI, Pacific. *γ*. Monsoon districts: XXVII, Indian; XXVIII, North Australian. *δ*. Districts with abundant rainfall in all months (doldrum rains): XXIX, East Indian; XXX, Suahelian; XXXI, Guinean; XXXII, Colombian; XXXIII, Selvan. The distribution of these types is shown in Plate II.*

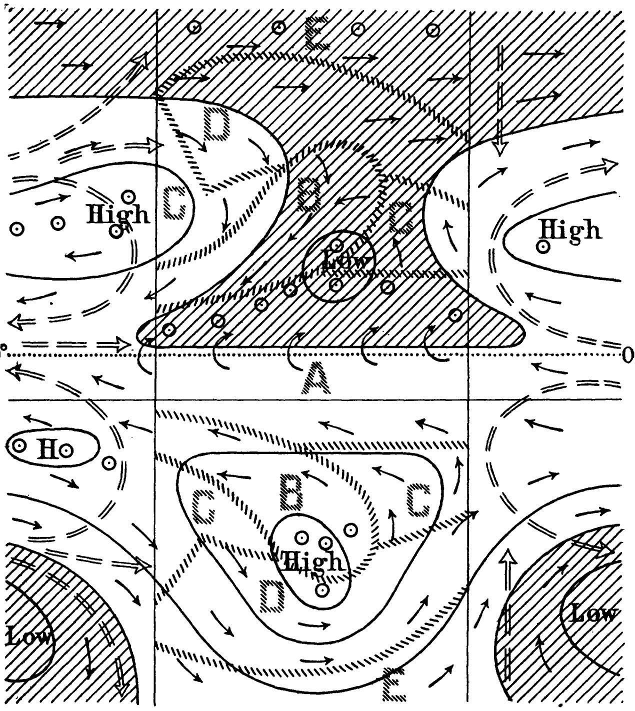

FIG. 7.—PRESSURE AND WINDS IN JULY.

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* From Hult, *vide supra*. On the chart here reproduced the smaller *provinces* are not shown.

Ravenstein's Hygrothermal Types.[*]—Recognizing the importance of relative humidity as a climatic factor in its influence upon life, upon agriculture and upon industry, and basing his grouping of climates upon certain relations between temperature and relative humidity, Ravenstein proposes a subdivision of the earth's surface into sixteen *hygrothermal* climatic types. The general characteristics and examples of these types are as follows:

1. Hot (73° and over) and very damp (humidity 81% or more): Batavia, Cameroons, Mombasa.
2. Hot and moderately damp (66–80%): Havana, Calcutta.
3. Hot and dry (51–65%): Bagdad, Lahore, Khartum.
4. Hot and very dry (50% or less): Disa, Wadi Halfa, Kuka.
5. Warm (58° to 72°) and very damp: Walvisch Bay, Arica.
6. Warm and moderately damp: Lisbon, Rome, Damascus, Tokio, New Orleans.
7. Warm and dry: Cairo, Algiers, Kimberley.
8. Warm and very dry: Mexico, Teheran.
9. Cool (33° to 57°) and very damp: Greenwich, Cochabamba.
10. Cool and moderately damp: Vienna, Melbourne, Toronto, Chicago.
11. Cool and dry: Tashkent, Simla, Cheyenne.
12. Cool and very dry: Yarkand, Denver.
13. Cold (32° or less) and very damp: Ben Nevis, Sagastyr, Godthaab.
14. Cold and moderately damp: Tomsk, Pike's Peak, Polaris House.
15. Cold and dry:
16. Cold and very dry: Pamir.

Classification of Rainfall Systems.—The seasonal occurrence of rainfall has suggested a classification of the rainfall systems of the world into types. While these schemes are useful in climatological study, they are hardly to be considered as classifications of climate. Mühry[†] gave a rigid scheme of rainfall types in six belts for each hemisphere, these belts being divided by latitude lines, and Köppen has prepared a useful map of the hyetal regions of the world based on the seasonal distribution of rainfall types.[‡]

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[*] E. G. Ravenstein: *The Geographic Distribution of Relative Humidity.* Rept. Brit. Ass. Adv. Sci., 1900, 817–818.

[†] A. Mühry: *Klimatographische Uebersicht der Erde*, Leipzig and Heidelberg, 1862, 741–744. Also: *Allgemeine geographische Meteorologie*, 1860, 145, and note 23, 199. Containing chart, as well as the scheme of rainfall types.

[‡] See *Atlas of Meteorology*, Plate 19.

Summary and Conclusions.—The broad classification of climates into the three general groups of marine, continental, and mountain, with the subordinate divisions of desert, littoral, and monsoon, is convenient for purposes of summarizing the interaction of the climatic elements under the controls of land, water, and altitude. But in any detailed study some scheme of classification is needed in which similar climates in different parts of the world are grouped together, and in which their geographic distribution receives particular consideration. It is obvious from the preceding paragraphs that an almost infinite number of classifications might be proposed; for we may take as the basis of subdivision either the special conditions of one climatic element, as, for example, the same mean annual temperature, or mean annual range of temperature, or the same rainfall, or rainy seasons, or humidity, and so on. Or again, similar conditions of the combination of two or more elements of climate may be made the basis of classification. Or we may take a botanical or a zoological basis. Of the classifications which have been proposed, special reference is here made to those of Supan, Köppen, and Hult. That of Supan, taken as a whole, gives a rational, simple, and satisfactory scheme of grouping, whose frequent use in climatic descriptions would tend toward system, simplicity, and facility of comparison. It emphasizes the essentials of each climate, and serves to impress these essentials upon the mind by means of the compact, well-considered verbal summary which is given in the case of each province described. Obviously, no classification of climates which is at all complete can approach the simplicity of the ordinary classification of the zones.

Köppen's admirable scheme of subdividing climates from the botanical point of view is distinctly rather for the use of students of plant geography than of general climatology. The present limits of the different climates in Köppen's map will doubtless need to be changed in several cases, as more detailed botanical studies throw further light on the geographical distribution of different plants, and no rigid delimitation of plant zones is ever satisfactory to everyone. But Köppen's classification has the great merit of recognizing the existing differences of climate between east and west coasts; and between coasts and interiors. The co-ordination of districts of vegetation and of climate, which this scheme so strikingly emphasizes, is a noteworthy fact in climatology.

Hult's classification is far too detailed, if all the smaller provinces are taken into account; but if only the larger kingdoms are considered, as in Plate II, the scheme is useful. It, however, possesses no advantages over that of Supan, which takes account of more typical characteristics of climate. Ravenstein's hygrothermal types rest upon unsatisfactory data, and regions of very different climatic conditions are grouped together because they happen to have the same mean annual temperature and relative humidity.

THE NORTH AMERICAN SHEETS OF STIELER'S HAND-ATLAS.

BY

FREDERICK J. H. MERRILL.

The sheets of Stieler's Hand-Atlas relating to North America command serious attention because of the high accuracy and authority of this work. They comprise a general map of North America, a general map of the United States, a six-sheet map of the United States, a two-sheet map of Canada, one of the West Indies and Central America, and one of Mexico. It is much to be regretted that no special sheet was prepared of Alaska, which promises so much in its mineral wealth.

The six-sheet map of the United States is of especial interest, because it is the only recent one of our country on which so high a degree of engraving skill has been concentrated, for the establishment of Justus Perthes in Gotha stands unsurpassed in the world for the exquisite delicacy of its work in geographic engraving.

To the editor of these sheets, Mr. Hermann Habenicht, belongs high credit for the painstaking labour he has bestowed on the compilation. There is, so far as the writer is aware, no map of the United States on which so much geographic detail is clearly shown on the small scale of 61 miles to the inch; and, so far as he can discover from a careful inspection of the sheets, there is practically nothing which has been omitted in the matter of topography and drainage The culture has also received careful attention; for the number of places with names is exceedingly great, and almost no place that has been located on any of the larger maps has been omitted from this laborious compilation. These maps, therefore, in point of completeness and accuracy of geographic detail, stand certainly unsurpassed, and probably unequalled.

To publish such a series of maps without errors of any sort would be beyond the scope of possibility; and on account of the international character of the publication, the writer has given a some-